MODULATION OF THE INTERACTION OF MUC1 WITH MUC1 LIGANDS

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FIELD OF THE INVENTION

The present invention relates generally to the field of cancer therapy, and more specifically, to the use of modulators or agents that interact with MUC1 as a point on intervention in cancer therapy.

BACKGROUND OF THE INVENTION

The human DF3/MUC1 transmembrane glycoprotein is aberrantly overexpressed by breast and other types of carcinomas (Kufe *et al.*, 1984). MUC1 expression is localized to the apical borders of normal secretory epithelial cells. In carcinoma cells, loss of polarity is associated with expression of MUC1 at high levels over the entire cell surface (Kufe *et al.*, 1984). Significantly, overexpression of MUC1 blocks apoptosis and is sufficient to confer cellular transformation (Li *et al.*, 2003b). The full-length MUC1 protein (MUC1-REP) is cleaved into N- and C-terminal subunits (N-ter (or ectodomain, "ED") and C-ter) that reside as a heterodimer at the cell membrane (Ligtenberg *et al.*, 1992; Parry *et al.*, 2001). The >250 kDa N-terminal ectodomain contains variable numbers of conserved 20 amino acid tandem repeats (VNTR region) that are extensively modified by O-glycosylation (Gendler *et al.*, 1988; Siddiqui *et al.*, 1988). The ~25 kDa C-ter includes an extracellular region of 58 amino acids (or extracellular domain, "ECD"), a 28 amino acid transmembrane domain and a 72 amino acid cytoplasmic tail. β-catenin, a component of the adherens junction of mammalian epithelial cells, binds directly to a SAGNGGSSL motif in the MUC1 cytoplasmic domain (Yamamoto *et al.*, 1997). The SAGNGGSSL motif also functions as a binding site for γ-catenin (plakoglobin) (Yamamoto *et al.*, 1997). The MUC1 C-ter is expressed at the cell membrane and in the nucleus where it colocalizes with β-catenin (Li *et al.*, 2003b; Li *et al.*, 2003c) and γ-catenin (Li *et al.*, 2003b).

The available evidence indicates that MUC1 functions in integrating signals from the Wnt and ErbB pathways. Glycogen synthase kinase 3β (GSK3β), an effector of Wnt signaling,

phosphorylates MUC1 on serine in a SPY site adjacent to that for β/γ-catenin binding (Li *et al.*, 1998). GSK3β-mediated phosphorylation of MUC1 decreases the interaction between MUC1 and β-catenin (Li *et al.*, 1998). The tyrosine in the SPY site is phosphorylated by c-Src and, in contrast to the effects of GSK3β, c-Src increases the interaction between MUC1 and β-catenin (Li *et al.*, 2001a). Phosphorylation of the MUC1 tail by protein kinase Cδ (PKCδ) also contributes to the interactions between MUC1 and β-catenin (Ren *et al.*, 2002). Other studies have shown that MUC1 forms a complex with the epidermal growth factor receptor (EGFR) (Li *et al.*, 2001b; Schroeder *et al.*, 2001). Stimulation of cells with EGF is associated with tyrosine phosphorylation of the SPY site and increased formation of MUC1-β-catenin complexes (Li *et al.*, 2001b). Conversely, exposure of cells to heregulin (HRG), a ligand for ErbB receptors, induces binding of MUC1 and γ-catenin (Li *et al.*, 2003c).

A number of splice variants of MUC1 have been described, including transmembrane proteins that lack the entire VNTR region. Such isoforms include MUC1/Y, MUC1/X and MUC1/Z (Zrihan-Licht *et al.*, 1994; Baruch *et al.*, 1997; Oosterkamp *et al.*, 1997; Obermair *et al.*, 2002).

SUMMARY OF THE INVENTION

The present invention provides for chimeric proteins comprising a MUC1-extracellular (MUC1-EC) polypeptide and a carrier polypeptide that function as traps for endogenous MUC1 ligands. For the purposes of the present invention, "MUC1-EC polypeptide" means a polypeptide derived from MUC1 REP extracellular domain or ectodomain or the extracellular domains of MUC1 transmembrane isoforms such as MUC1/Y, MUC1/X and MUC1/Z. "Carrier polypeptide" means a polypeptide that, when present in a chimeric protein comprising a MUC1-EC polypeptide, will increase the serum half-life of the chimeric protein as compared to the serum half-life of the MUC1-EC polypeptide alone. Examples of carrier polypeptides include those derived from human immunoglobulin FC polypeptides and those derived from human albumin polypeptides. A "MUC1 ligand trap" means a polypeptide that will bind to a MUC1 ligand. "MUC1 ligand" means a ligand that binds to the extracellular and/or ectodomain, excluding the VNTR region, of MUC1 or binds to the extracellular domain of MUC1 isoforms that lack the VNTR region. By "trapping" MUC1 ligands, the MUC1-EC chimeric proteins of the present invention intercept MUC1 ligands prior to binding to MUC1 presented on the plasma membrane of cancer cells and thereby decrease or substantially prevent MUC1-mediated oncogenic signaling.

One aspect of the present invention is a MUC1 chimeric protein, which may be a fusion protein, comprising a first polypeptide sequence and a second polypeptide sequence, wherein the first polypeptide sequence is a MUC1-EC polypeptide and the second polypeptide sequence is a carrier polypeptide which may be a human immunoglobulin FC polypeptide or a human albumin polypeptide. In various embodiments, the MUC1-EC polypeptide is selected from the group consisting of SEQ ID NO: 1, SEQ ID NO: 3, SEQ ID NO: 5, SEQ ID NO: 7, SEQ ID NO: 9, SEQ ID NO: 11, SEQ ID NO: 13, SEQ ID NO: 15, SEQ ID NO: 17, SEQ ID NO: 19, SEQ ID NO: 21, SEQ ID NO: 23, SEQ ID NO: 25, SEQ ID NO: 27, SEQ ID NO: 29 and SEQ ID NO: 31. In some embodiments, the MUC1-EC polypeptide binds dermcidin and/or PLU-1. In some embodiments the human immunoglobulin FC polypeptide is a human IgG FC polypeptide, which may be a IgG1 or IgG2 FC polypeptide. In some embodiments, a MUC1 chimeric protein comprising an immunoglobulin FC polypeptide may further comprise a second MUC1 chimeric protein comprising an immunoglobulin FC polypeptide, wherein the two MUC1 chimeric proteins comprising immunoglobulin FC polypeptides form a dimer by means of one or more disulfide bridges formed between the hinge regions of the immunoglobulin FC polypeptides. The two MUC1-EC polypeptides in the dimer may be the same or different.

The invention also encompasses a pharmaceutical composition comprising a pharmaceutically acceptable carrier and a MUC1 chimeric protein comprising a first polypeptide sequence and a second polypeptide sequence, wherein the first polypeptide sequence is a MUC1-EC polypeptide and the second polypeptide sequence is a carrier polypeptide.

Other aspects of the invention include methods of inhibiting or killing a MUC1-expressing cancer cell comprising contacting the MUC1-expressing cancer cell with an effective amount of a MUC1 chimeric protein comprising a first polypeptide sequence and a second polypeptide sequence, wherein the first polypeptide sequence is a MUC1-EC polypeptide and the second polypeptide sequence is a carrier polypeptide, which may be a human immunoglobulin FC polypeptide or a human albumin polypeptide. A MUC1-expressing cancer cell means a cancer cell that expresses MUC1-REP and/or one or more types of transmembrane MUC1 isoforms lacking the VNTR region. The methods may further comprise contacting the MUC1-expressing cancer cell with an effective amount of a chemotherapeutic agent or exposing the MUC1-expressing cancer cell with an effective dose of ionizing radiation.

A further aspect of the present invention is a method of treating cancer in a patient comprising administering an effective amount of MUC1 chimeric protein comprising a first polypeptide sequence and a second polypeptide sequence, wherein the first polypeptide sequence

is a MUC1-EC polypeptide and the second polypeptide sequence is a carrier polypeptide, which may be a human immunoglobulin FC polypeptide or a human albumin polypeptide.

Another aspect of the present invention provides for the modulation of the binding of dermcidin to MUC1 in addition to the use of the MUC1 ligand trap described above. Thus, the present invention provides for methods of inhibiting the expression of dermcidin through gene silencing, inhibition of dermcidin-dependent signaling via use of dermcidin antibodies and aptamers. The invention also provides for screening methods for the identification of compounds that inhibit the binding of dermcidin to MUC1.

DETAILED DESCRIPTION OF THE INVENTION

I. Polypeptides

The present invention provides for chimeric proteins comprising a MUC1-EC polypeptide and a carrier polypeptide. Such chimeric proteins may be provided as fusion proteins or proteins wherein the MUC1-EC polypeptide and carrier polypeptide are otherwise chemically linked together.

The polypeptides of the present invention include variant polypeptides. By "variant" polypeptide is intended a polypeptide sequence modified by deletion or addition of one or more amino acids at one or more sites in the sequence; or substitution of one or more amino acids at one or more sites within the sequence. Variant polypeptides encompassed by the present invention retain the desired biological activity of the polypeptide from which they are derived. Such variants will have at least 40%, 50%, 60%, 70%, generally at least 75%, 80%, 85%, preferably about 90% to 95% or more, and more preferably about 98% or more sequence identity to the amino acid sequence of the polypeptide from which they are derived. The percentage of sequence identity, also termed homology, between a polypeptide native and a variant sequence may be determined by comparing the two sequences using the Gap program (Wisconsin Sequence Analysis Package, Version 8 for Unix, Genetics Computer Group, University Research Park, Madison Wisconsin), which uses the algorithm of Smith and Waterman, (1981).

The polypeptides of the present invention also include variant polypeptides with one or more conservative substitutions. For the purposes of classifying amino acid substitutions as conservative, amino acids are grouped as follows: Group I (hydrophobic sidechains): norleucine, met, ala, val, leu, ile; Group II (neutral hydrophilic side chains): cys, ser, thr; Group III (acidic side chains): asp, glu; Group IV (basic side chains): asn, gin, his, lys, arg; Group V

(residues influencing chain orientation): gly, pro; and Group VI (aromatic side chains): trp, tyr, phe. Conservative substitutions involve substitutions between amino acids in the same class.

Also encompassed by the present invention are chemical derivatives of polypeptides. "Chemical derivative" refers to a subject polypeptide having one or more residues chemically derivatized by reaction of a functional side group. Such derivatized residues include, for example, those molecules in which free amino groups have been derivatized to form amine hydrochlorides, *p*-toluene sulfonyl groups, carbobenzoxy groups, *t*-butyloxycarbonyl groups, chloroacetyl groups or formyl groups. Free carboxyl groups may be derivatized to form salts, methyl and ethyl esters or other types of esters or hyrazides. Free hydroxyl groups may be derivatized to form O-acyl or O-alkyl derivatives. The imadazole group of histidine may be derivatized to form N-imbenzylhistidine.

The term "polypeptide" as used herein indicates a molecular chain of amino acids and does not refer to a specific length of the product.

A. MUC1-ECD Polypeptides

The present invention relates to chimeric proteins comprising MUC1-EC polypeptides. MUC1-EC polypeptides may be derived from the sequence for MUC1-REP, wherein tandem repeats may be present, as in SEQ ID NO: 13, or all tandem repeat sequences are deleted, as in SEQ ID NO: 15. Further deletions may be made from the amino-terminal, such as exemplified in SEQ ID NO: 17, 19 and 23, or the carboxy-terminal, as exemplified in SEQ ID NO: 21. MUC1-REP is cleaved during intercellular processing between the glycine and the serine in the sequence FRPGSVVV, wherein the amino-terminal and carboxy-terminal fragments associate as a heterodimer (Parry *et al.*, 2001). The heterodimer is apparently very stable, being resistant to boiling, urea, sulfhydryl compounds, low pH or high salt (Julian & Carson, 2002), and thus would be expected to be purified as a heterodimer. Thus, the present invention also encompasses the heterodimer forms of MUC1-EC fusion proteins to the extent they are cleaved as in the intercellular processing of MUC1-REP.

MUC1 polypeptides may also be derived from the sequence for the splice variant MUC1/Y (see *e.g.*, Zirhan-Licht *et al.*, 1994; GenBank S48146[gi:1085342]), wherein SEQ ID NO: 1 and SEQ ID NO: 3 exemplify two amino-terminal variants. SEQ ID NO 11 represents a further 102 amino acid truncated from. The polynucleotide sequences for the forgoing MUC1-EC polypeptides are exemplified in SEQ ID NO: 2, 4, 6, 8, 10, 12, 14, 16 and 18.

MUC1-EC polypeptides are also derived from other MUC1 splice variants. SEQ ID NO: 5 represents a MUC1-EC derived from a splice variant that has been called both MUC1/Z

(Oosterkamp *et al.*, 1997; GenBank AAD10858[gi:4204967]) and MUC1/X (Baruch *et al.*, 1997). SEQ ID NO: 7 represents a MUC1-EC derived from a splice variant that has been termed MUC1/V (WO9603502). SEQ ID NO: 9 represents a MUC1-EC derived from a splice variant that has been termed called MUC1/X (GenBank AAD10856[gi:4204963]. The present invention also includes variants of SEQ ID NO: 5, 7 and 9 that comprise the longer amino-terminal sequence as found in SEQ ID NO: 1 and variants truncated from the amino-terminus, *e.g.*, SEQ ID NO: 25 and 27, and/or from the carboxy-terminus, *e.g.*, SEQ ID NO: 29 and 31.

The polynucleotide sequences for the foregoing exemplified MUC1-EC polypeptides are provided in SEQ ID NO: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30 and 32.

In one aspect of the present invention, the MUC1-EC polypeptide is SEQ ID NO: 1, SEQ ID NO: 3, SEQ ID NO: 7, or a fragment or substitutional variant thereof that binds dermcidin (DCD), Y-P30 peptide, and/or PLU-1. DCD is a diffusible neural survival evasion peptide (Cunningham *et al.* 2002) that has been proposed as a candidate oncogene in breast cancer (Porter *et al.*, 2003). Y-P30 is a DCD derived peptide that retains the neuronal survival promoting properties (Cunningham, 1998; Cunningham 2000). PLU-1 is a nuclear protein that is up-regulated in breast cancer (Barret *et al.*, 2002).

B. Immunoglobulin Polypeptides

One aspect of the present invention encompasses MUC1-EC chimeric proteins comprising the FC portion of human immunoglobulins as a carrier polypeptide. The basic unit of an immunoglobulin molecule consists of two identical heavy chains and two identical light chains. The amino-terminus of each chain contains a region of variable amino acid sequence (variable region). The variable regions of the heavy and light chains interact to form two antigen binding sites. The carboxy-terminus of each chain contains a region of constant amino acid sequence (constant region). The light chain contains a single constant domain, whereas the heavy chain constant domain is subdivided into four rate domains (CH1, hinge, CH2, and CH3). The heavy chains of immunoglobulin molecules are of several types, including mu (M), delta (D), gamma (G), alpha (A) and epsilon (E). An immunoglobulin molecule derives its name from the type of heavy chain that it possesses.

"FC" originally stood for "fragment crystallizable" and is derived from a rabbit IgG antibody fragment isolated and defined following digestion with papain. "FC" is now more usefully thought as "fragment complement binding" and generally comprises the C-terminal half of the heavy chain including that part of the hinge region containing the heavy-chain disulphide bridges. The FC portion of immunoglobulins controls the rate of catabolism of the molecules

(serum half-lives in the range of two to three weeks). For the purposes of the present invention, "FC" means an immunoglobulin fragment comprising the CH2 and CH3 domains and wherein the hinge region is present, partially present, modified by deletions or substitutions, or is absent. "Human FC" means an FC portion derived from heavy chain types G, M, D, A and E.

SEQ ID NO: 33 represents the amino acid sequence of the hinge, CH2 and CH3 regions of IgG1, and is capable of forming dimers via inter-chain disulfide bridges via the cysteines at residues 11 and 14. SEQ ID NO: 34 provides the corresponding coding polynucleotide sequence for SEQ ID NO: 33. Embodiments of the present invention include the full sequence of SEQ ID NO: 33 and truncated versions, such as deletion of the first five amino acids, the cysteine at residues 5, or the full hinge region (first amino-terminal 16 amino acid residues). Other embodiments encompass suitable mutations, such as substitution of alanine for the cysteine at residue position 5. An example of a variant IgG1 polypeptide sequence is shown in SEQ ID NO: 35, coded by the polynucleotide sequence shown in SEQ ID NO: 36.

SEQ ID NO: 37 represents the amino acid sequence of the hinge, CH2 and CH3 regions of IgG2. SEQ ID NO: 38 provides the corresponding coding polynucleotide sequence for SEQ ID NO: 37. Embodiments of the invention include in addition to the full sequence of SEQ ID NO: 37, deletions and substitutional deletions of the hinge region, *i.e.*, amino-terminal 12 amino acid residues, including deletion of all the hinge region or deletion or substitution of one or more of the cysteine residues.

SEQ ID NO: 39 represents the amino acid sequence of the hinge, CH2 and CH3 regions of IgG4. SEQ ID NO: 40 provides the corresponding coding polynucleotide sequence for SEQ ID NO: 39. Embodiments of the invention include in addition to the full sequence of SEQ ID NO: 39, deletions and substitutional deletions of the hinge region, *i.e.*, amino-terminal 12 amino acid residues, including deletion of all the hinge region or deletion or substitution of one or more of the cysteine residues. In one example of a suitable substitution, the serine at amino acid residue 10 is substituted with proline. Also, substitutions may be made in the CH2 region, for example, the leucine at amino acid residue 17 is substituted with glutamate.

MUC1-EC chimeric proteins comprising immunoglobulin FC polypeptides containing functional hinge regions are capable of forming dimers via disulfide bridges. Such dimers are encompassed by the present invention wherein the dimers may comprise the same or different MUC1-EC polypeptides.

C. Albumin Polypeptides

One aspect of the present invention encompasses MUC1-ECD fusion proteins comprising a carrier polypeptide derived from albumin. Human albumin is an abundant non-glycosylated plasma protein with a slow clearance profile and has been employed as a fusion partner to slow the clearance of other proteins (see *e.g.*, Yeh *et al.*, 1992, incorporated herein by reference). The terms, human serum albumin (HSA) and human albumin (HA) are used interchangeably herein. The amino acid and polynucleotide sequences for albumin are provided in SEQ ID NO: 41 and 42 respectively. The fusion proteins of the invention encompass MUC1-EC chimeric proteins comprising the full sequence of SEQ ID NO: 41 plus truncated albumins and/or albumins modified by substitutions, *e.g.*, as described in U.S. Patents 5,965,386, 5,380,712 and 5,766,883, all incorporated herein by reference.

II. Chimeric Proteins

The present invention provides for chimeric proteins comprising a MUC1-EC polypeptide and a carrier polypeptide. Such chimeric proteins may be MUC1-EC fusion proteins and isolated DNA sequences encoding the MUC1-EC fusion proteins are also provided by the present invention. A DNA sequence encoding a fusion protein of the present invention is constructed using recombinant DNA techniques to insert DNA fragments encoding the MUC1-EC or carrier polypeptides into an appropriate expression vector. The 3' end of a DNA fragment encoding a MUC1-ECD is ligated (via a peptide linker) to the 5' end of the DNA fragment encoding a carrier polypeptide with the reading frames of the sequences in phase to permit translation of the mRNA into a single fusion protein. Alternatively, the 3' end of a DNA fragment encoding a carrier protein may be ligated (via a peptide linker) to the 5' end of the DNA fragment encoding a MUC1-EC, with the reading frames of the sequences in phase to permit translation of the mRNA into a single biologically active fusion protein. The MUC1-EC encoding sequence is preferably positioned upstream of the carrier polypeptide encoding sequence. A DNA sequence encoding an N-terminal signal sequence may be retained on the DNA sequence encoding the N-terminal polypeptide, while stop codons, which would prevent read-through to the downstream DNA sequence(s), are eliminated. Conversely, a stop codon required to end translation is generally retained on the DNA sequence encoding the C-terminal polypeptide. DNA encoding a signal sequence is preferably removed from DNA sequences other than those encoding the N-terminal polypeptide.

A DNA sequence encoding a desired peptide linker may be inserted between, and in the same reading frame as, the DNA sequences encoding MUC1-EC or carrier polypeptides using

any suitable conventional technique. For example, a chemically synthesized oligonucleotide encoding the linker and containing appropriate restriction endonuclease cleavage sites may be ligated between the sequences encoding MUC1-EC or carrier polypeptide. Alternatively, a chemically synthesized DNA sequence may contain a sequence complementary to the 3' terminus (without the stop codon) of either MUC1-EC or carrier polypeptide followed by a linker-encoding sequence which is followed by a sequence complementary to the 5' terminus of the other of MUC1-EC or carrier polypeptide. Oligonucleotide directed mutagenesis is then employed to insert the linker-encoding sequence into a vector containing a direct fusion of MUC1-EC and carrier polypeptide. Another technique employs polymerase chain reactions using primers comprising, in part, single strand segments encoding a peptide linker. PCR-generated DNA fragments encoding two different proteins can be joined through annealing of the complementary single stranded linker-encoding segments present at a terminus of each fragment.

DNA sequences encoding MUC1-EC and carrier polypeptide may be isolated by any suitable conventional procedure, for use in constructing the fusion protein-encoding DNA sequences of the present invention. DNA sequences encoding fusion proteins to be expressed in a microorganism will typically contain no introns that could prematurely terminate transcription of DNA into mRNA; however, premature termination of transcription may be desirable, for example, where it would result in mutants having advantageous C-terminal truncations.

The coding sequence of MUC1-EC polypeptides may be obtained by isolating a sequence encoding a MUC1-EC from a recombinant cDNA or genomic DNA library. A cDNA library is preferably constructed by obtaining polyadenylated mRNA from a particular cell line which expresses a human MUC1-EC and using the mRNA as a template for synthesizing double-stranded cDNA. The double-stranded cDNA is then packaged into a recombinant vector, which is introduced into a host cell and propagated. MUC1-EC sequences contained in the cDNA library can be identified by screening the library with an appropriate nucleic acid probe which is capable of hybridizing with human MUC1-EC cDNA. Another cloning technique that may be employed is a direct expression procedure or DNAs encoding MUC1-EC polypeptides can be assembled by ligation of synthetic oligonucleotide subunits corresponding to all or part of the desired sequence.

DNA encoding soluble MUC1-EC and carrier polypeptides may be prepared by any of a number of conventional techniques. A DNA fragment encoding a desired soluble polypeptide may be subcloned into an expression vector. DNA fragments may be produced by restriction endonuclease digestion of a full-length cloned DNA sequence, and isolated by electrophoresis on

agarose gels. Alternatively, a desired DNA sequence may be chemically synthesized using known techniques. Linkers containing restriction endonuclease cleavage site(s) may be employed to insert the desired DNA fragment into an expression vector, or the fragment may be digested at cleavage sites naturally present therein. The polymerase chain reaction (PCR) procedures also may be employed to isolate a DNA sequence encoding a desired soluble protein fragment.

In another approach, enzymatic treatment (using Bal 31 exonuclease) may be employed to delete terminal nucleotides from a DNA fragment to obtain a fragment having a particular desired terminus. Among the commercially available linkers are those that can be ligated to the blunt ends produced by Bal 31 digestion, and which contain restriction endonuclease cleavage site(s). Alternatively, oligonucleotides that reconstruct the N- or C-terminus of a DNA fragment to a desired point may be synthesized. The oligonucleotide may contain a restriction endonuclease cleavage site upstream of the desired coding sequence and position an initiation codon (ATG) at the N-terminus of the coding sequence.

The present invention provides recombinant expression vectors to express DNA encoding the fusion proteins of the present invention. The recombinant expression vectors are replicable DNA constructs which contain a synthetic or cDNA-derived DNA sequence encoding one of the above-described fusion proteins, operably linked to suitable transcriptional or translational regulatory elements. Examples of genetic elements having a regulatory role in gene expression include transcriptional promoters, operators or enhancers, a sequence encoding suitable mRNA ribosomal binding sites, and appropriate transcription and translation initiation and termination sequences. The ability to replicate in a host, usually conferred by an origin of replication, and a selection gene to facilitate recognition of transformants may additionally be incorporated. The regulatory elements employed in the expression vectors are generally derived from mammalian, microbial, viral, or insect genes. Expression vectors derived from retroviruses also may be employed.

DNA regions are operably linked when they are functionally related to each other. A DNA sequence encoding a fusion protein is said to be operably linked to one or more of the above-described regulatory elements when the fusion protein DNA sequence is transcribed, or the resulting mRNA is translated, under the control of the regulatory element(s).

Transformed host cells are cells that have been transformed or transfected with foreign DNA using recombinant DNA techniques. In the context of the present invention, the foreign DNA includes a sequence encoding the inventive fusion protein. Host cells may be transformed for purposes of cloning or amplifying the foreign DNA, or may be transformed with an

expression vector for production of the fusion protein under the control of appropriate promoters. Suitable host cells include prokaryotes, yeast, or in some preferred embodiments, higher eukaryotic cell. Appropriate cloning and expression vectors for use with bacterial, fungal, yeast, and mammalian cellular hosts are described by Pouwels *et al.* (1985), the relevant disclosures of which is hereby incorporated by reference. Cell-free translation systems could also be employed to produce fusion protein using RNAs derived from the DNA constructs of the present invention.

Prokaryotes include gram negative or gram positive organisms. Prokaryotic expression vectors generally comprise one or more phenotypic selectable markers, for example a gene encoding proteins conferring antibiotic resistance or supplying an autotrophic requirement, and an origin of replication recognized by the host to ensure amplification within the host. Examples of suitable prokaryotic hosts for transformation include *E. coli*, bacilli such as *Bacillus subtilis*, *Salmonella typhimurium*, and various species within the genera *Pseudomonas*, *Streptomyces*, and *Staphylococcus*, although others may also be employed as a matter of choice.

Useful expression vectors for bacterial use can comprise a selectable marker and bacterial origin of replication derived from commercially available plasmids comprising genetic elements of the well-known cloning vector pBR322 (ATCC 37017). Such commercial vectors include, for example, pKK223-3 (Amersham Biosciences, Piscataway, NJ) and pGEM1 (Promega Biotec, Madison, WI., USA). These pBR322 "backbone" sections are combined with an appropriate promoter and the structural sequence to be expressed. *E. coli* is typically transformed using derivatives of pBR322, a plasmid derived from an *E. coli* species (Bolivar *et al.*, 1977). pBR322 contains genes for ampicillin and tetracycline resistance, providing simple means for identifying transformed cells.

Promoters commonly used in recombinant microbial expression vectors include the b-lactamase (penicillinase) and lactose promoter system (Chang *et al.*, 1978; and Goeddel *et al.*, 1979), the tryptophan (trp) promoter system (Goeddel *et al.*, 1980) and tac promoter (Maniatis, 1982). A particularly useful bacterial expression system employs the phage λP_L promoter and cI857ts thermoinducible repressor. Plasmid vectors available from the American Type Culture Collection which incorporate derivatives of the λP_L promoter include plasmid pHUB2, resident in E. coli strain JMB9 (ATCC 37092) and pPLc28, resident in *E. coli* RR1 (ATCC 53082).

The recombinant fusion protein may also be expressed in yeast hosts, preferably from Saccharomyces species, such as *S. cerevisiae*. Yeast of other genera such as *Pichia* or *Kluyveromyces* may also be employed. Yeast vectors will generally contain an origin of replication from the 2 μm yeast plasmid or an autonomously replicating sequence (ARS), a promoter, DNA encoding the fusion protein, sequences for polyadenylation and transcription

termination and a selection gene. Preferably, yeast vectors will include an origin of replication and selectable markers permitting transformation of both yeast and *E. coli, e.g.*, the ampicillin resistance gene of *E. coli* and the *S. cerevisiae* trp 1 gene, which provides a selection marker for a mutant strain of yeast lacking the ability to grow in tryptophan, and a promoter derived from a highly expressed yeast gene to induce transcription of a structural sequence downstream. The presence of the trp1 lesion in the yeast host cell genome then provides an effective environment for detecting transformation by growth in the absence of tryptophan.

Suitable promoter sequences in yeast vectors include the promoters for metallothionein, 3-phosphoglycerate kinase (Hitzeman *et al.*, 1980) or other glycolytic enzymes (Hess *et al.*, 1968; Holland *et al.*, 1978), such as enolase, glyceraldehyde-3-phosphate dehydrogenase, hexokinase, pyruvate decarboxylase, phosphofructokinase, glucose-6-phosphate isomerase, 3-phosphoglycerate mutase, pyruvate kinase, triosephosphate isomerase, phosphoglucose isomerase and glucokinase.

Preferred yeast vectors can be assembled using DNA sequences from pBR322 for selection and replication in *E. coli* (Amp^r gene and origin of replication) and yeast DNA sequences including a glucose-repressible ADH2 promoter and α-factor secretion leader. The ADH2 promoter has been described by Russell *et al.* (1982) and Beier *et al.*, (1982). Advantageously, a DNA segment encoding a leader sequence functional in yeast is operably linked to the 5' end of the DNA encoding the fusion protein. The encoded leader peptide promotes secretion of the fusion protein from the host cell and is generally cleaved from the fusion protein upon secretion. As one example, the yeast α-factor leader, which directs secretion of heterologous proteins, can be inserted between the promoter and the structural gene to be expressed. See, *e.g.*, Kurjan *et al.*, (1982); Bitter *et al.*, (1984). The leader sequence may be modified to contain, near its 3' end, one or more useful restriction sites to facilitate fusion of the leader sequence to foreign genes.

Suitable yeast transformation protocols are known to those of skill in the art. An exemplary technique is described by Hinnen *et al.* (1978), selecting for Trp^+ transformants in a selective medium consisting of 0.67% yeast nitrogen base, 0.5% casamino acids, 2% glucose, 10 μg/ml adenine and 20 μg/ml uracil. Host strains transformed by vectors comprising the above-described ADH2 promoter may be grown for expression in a rich medium consisting of 1% yeast extract, 2% peptone, and 1% glucose supplemented with 80 μg/ml adenine and 80 μg/ml uracil. Derepression of the ADH2 promoter occurs upon exhaustion of medium glucose. Crude yeast supernatants are harvested by filtration and held at 4°C prior to further purification.

Various mammalian or insect cell culture systems can be employed to express recombinant protein. Baculovirus systems for production of heterologous proteins in insect cells are reviewed by Luckow & Summers, (1988). Established cell lines of mammalian origin may be employed. Examples of suitable mammalian host cell lines include the COS-7 lines of monkey kidney cells (described by Gluzman, 1981), L cells, C127, 3T3, Chinese hamster ovary (CHO), HeLa and BHK cell lines. Mammalian expression vectors may comprise non-transcribed elements such as an origin of replication, a suitable promoter and enhancer linked to the gene to be expressed, and other 5' or 3' flanking nontranscribed sequences, and 5' or 3' nontranslated sequences, such as necessary ribosome binding sites, a poly-adenylation site, splice donor and acceptor sites, and transcriptional termination sequences.

The transcriptional and translational control sequences in expression vectors to be used in transforming vertebrate cells may be provided by viral sources. For example, commonly used promoters and enhancers are derived from Polyoma, Adenovirus 2, Simian Virus 40 (SV40), and human cytomegalovirus. DNA sequences derived from the SV40 viral genome, for example, SV40 origin, early and late promoter, enhancer, splice, and polyadenylation sites may be used to provide the other genetic elements required for expression of a heterologous DNA sequence. The early and late promoters are particularly useful because both are obtained easily from the virus as a fragment that also contains the SV40 viral origin or replication (Fiers *et al.*, 1978). Smaller or larger SV40 fragments may also be used, provided the approximately 250 bp sequence extending from the Hind III site toward the BglI site located in the viral origin of replication is included. Exemplary vectors can be constructed as disclosed by Okayama & Berg (1983). A useful system for stable high level expression of mammalian receptor cDNAs in C127 murine mammary epithelial cells can be constructed substantially as described by Cosman *et al.* (1986).

The present invention provides a process for producing the recombinant fusion protein of the present invention, comprising culturing a host cell transformed with an expression vector comprising a DNA sequence that encodes said fusion protein under conditions that promote expression of the fusion protein, which is then purified from culture media or cell extracts. Any suitable purification process may be employed, with the procedure of choice varying according to such factors as the type of host cells and whether or not the desired protein is secreted from the host cells. The fusion protein will be secreted into the culture medium when it is initially fused to a signal sequence or leader peptide operative in the host cells, or when the protein comprises soluble forms of the MUC1-EC and carrier polypeptides.

For example, supernatants from expression systems that secrete recombinant protein into the culture medium can be first concentrated using a commercially available protein

concentration filter, for example, an Amicon or Millipore Pellicon ultrafiltration unit. Following the concentration step, the concentrate can be applied to a suitable purification matrix. For example, a suitable affinity matrix can comprise antibodies to MUC1-EC or carrier polypeptides. An affinity matrix may be prepared by coupling antibodies to cyanogen bromide-activated Sepharose (Pharmacia) or Hydrazide Affigel (Biorad), according to manufacturer's recommendations. A preferred purification procedure involves sequential immunopurification using antibodies bound to a suitable support. Proteins binding to an antibody specific for MUC1-EC or carrier polypeptide are recovered and contacted with antibody specific for IL-1R on an insoluble support. Proteins immunoreactive with both antibodies may thus be identified and isolated. Alternatively, an anion exchange resin can be employed, for example, a matrix or substrate having pendant diethylaminoethyl (DEAE) groups. The matrices can be acrylamide, agarose, dextran, cellulose or other types commonly employed in protein purification. Alternatively, a cation exchange step can be employed. Suitable cation exchangers include various insoluble matrices comprising sulfopropyl or carboxymethyl groups. Sulfopropyl groups are preferred. One or more reversed-phase high performance liquid chromatography (RP-HPLC) steps employing hydrophobic RP-HPLC media, *e.g.*, silica gel having pendant methyl or other aliphatic groups, can be employed to further purify a fusion protein composition.

Recombinant protein produced in bacterial culture is usually isolated by initial extraction from cell pellets, followed by one or more concentration, salting-out, aqueous ion exchange or size exclusion chromatography steps. Finally, high performance liquid chromatography (HPLC) can be employed for final purification steps. Microbial cells employed in expression of recombinant fusion proteins can disrupted by any convenient method, including freeze-thaw cycling, sonication, mechanical disruption, or use of cell lysing agents.

Fermentation of yeast which express fusion proteins as a secreted protein greatly simplifies purification. Secreted recombinant protein resulting from a large-scale fermentation can be purified by methods analogous to those disclosed by Urdal *et al.* (1984), involving two sequential, reversed-phase HPLC steps for purification of a recombinant protein on a preparative HPLC column.

Some or all of the foregoing purification steps, in various combinations, can be employed to provide an essentially homogeneous recombinant protein. Recombinant cell culture enables the production of the fusion protein free of those contaminating proteins which may be normally associated with MUC1-EC or carrier polypeptides as they are found in nature, e.g., in cells, cell exudates or body fluids.

As an alternative to production of the inventive chimeric proteins as fusion proteins, the MUC1-EC and carrier polypeptides may be separately produced and purified, and subsequently linked together. Numerous reagents useful for crosslinking one protein molecule to another are known. Heterobifunctional and homobifunctional linkers are available for this purpose from Pierce Chemical Company, Rockford, Ill., for example. Such linkers contain two functional groups (*e.g.*, esters and/or maleimides) that will react with certain functional groups on amino acid side chains (*e.g.*, amines on lysine residues and sulfhydryls generated on cysteine residues by reduction), thus linking one polypeptide to another. Examples of such crosslinking reagents are N-maleimidobenzoyl succinimidyl ester and N-hydroxysuccinimide. The reagent and reaction conditions should be chosen such that the cross-linking does not interfere with binding of MUC1-EC to ligands. The MUC1-EC and carrier polypeptides are preferably linked via one of the above-described peptide linkers that functions as a spacer. A peptide linker may be attached to MUC1-EC or carrier polypeptides by any of the conventional procedures used to attach one polypeptide to another. Amino acids having side chains reactive with such reagents may be included in the peptide linker, *e.g.*, at the termini thereof.

III. Antibodies

In regard to the term "antibody" as used for antibodies directed at MUC-1 ligand epitopes, the term is used in the broadest sense and specifically covers monoclonal antibodies (including full length monoclonal antibodies), polyclonal antibodies, multispecific antibodies (*e.g.*, bispecific antibodies), and antibody fragments, so long as they exhibit the desired biological activity.

In regard to dermcidin antibodies, the antibodies are raised against an epitope within SEQ ID NO: 43, and in some embodiments towards an epitope within the amino acid sequence of the mature polypeptide, residues 20 to 110 of SEQ ID NO: 43, and in another embodiment to a recognition site within amino acid residues 20 to 49 of SEQ ID NO: 43. In other embodiments, the dermcidin antibody recognizes an epitope within amino acid residues 20 to 30, or within amino acid residues 25 to 35, or within amino acid residues 30 to 40, or within amino acid residues 45 to 55, of SEQ ID NO: 43.

Methods for generating polyclonal antibodies are well known in the art. Briefly, a polyclonal antibody is prepared by immunizing an animal with an immunogenic composition and collecting antisera from that immunized animal. A wide range of animal species can be used for the production of antisera including rabbit, mouse, rat, hamster, guinea pig and goat. The serum for an immunized animal may be used as is for various applications or the desired

antibody fraction may be purified by well-known methods, such as affinity chromatography using another antibody or a peptide bound to a solid matrix.

Monoclonal antibodies (MAbs) may be readily prepared through use of well-known techniques, such as those exemplified in U.S. Patent 4,196,265, incorporated herein by reference. Typically, this technique involves immunizing a suitable animal with a selected immunogen composition, *e.g.*, a purified or partially purified expressed polypeptide. The immunizing composition is administered in a manner that effectively stimulates antibody producing cells, which may comprise, but is not limited to, administration of MUC1 ligand derived peptides or transgenic cells expressing a MUC1 ligand.

The methods for generating monoclonal antibodies (MAbs) generally begin along the same lines as those for preparing polyclonal antibodies. The use of rats may provide certain advantages (Goding, 1986), but mice are preferred, with the BALB/c mouse being the most routinely used and generally gives a higher percentage of stable fusions. Human antibodies may be prepared from immunized xenomice as described by U.S. Patent 6,075,181 and U.S. Patent 6,150,584, both incorporated herein by reference.

Following immunization, somatic cells with the potential for producing antibodies, specifically B lymphocytes (B cells), are selected for use in the MAb generating protocol. These cells may be obtained from biopsied spleens, tonsils or lymph nodes, or from a peripheral blood sample. Spleen cells and peripheral blood cells are preferred. Often, a panel of animals will have been immunized and the spleen of animal with the highest antibody titer will be removed for obtaining lymphocytes from the spleen.

The antibody-producing B lymphocytes from the immunized animal are then fused with cells of an immortal myeloma cell, generally one of the same species as the animal that was immunized. Myeloma cell lines suited for use in hybridoma-producing fusion procedures preferably are non-antibody-producing, have high fusion efficiency, and have enzyme deficiencies that render them incapable of growing in certain selective media that support the growth of only the desired fused cells (hybridomas). Selected hybridomas are serially diluted and cloned into individual antibody-producing cell lines, which can then be propagated indefinitely to provide MAbs.

In accordance with the present invention, fragments of the monoclonal antibody of the invention can be obtained from the monoclonal antibody produced as described above, by methods which include digestion with enzymes such as pepsin or papain and/or cleavage of disulfide bonds by chemical reduction. Alternatively, monoclonal antibody fragments encompassed by the present invention can be synthesized using an automated synthesizer, or by

expression of full-length gene or of gene fragments in *E. coli* or other recombinant microorganisms and cell lines.

The present invention also encompasses various antibody conjugates. Labeled conjugates are useful in various screening and diagnostic uses such as flow cytometry, immunohistochemistry and immuno-quantification methods such as ELISA techniques. Labels used in making versions of the antibodies of the present invention suitable for screening and diagnostic uses include moieties that may be detected directly, such as fluorochromes and radiolabels, as well as moieties, such as enzymes, that must be reacted or derivatized to be detected. Examples of such labels are ^{32}P, ^{125}I, ^{3}H, ^{14}C, fluorescein and its derivatives, rhodamine and its derivatives, dansyl, umbelliferone, luciferia, 2,3-dihydrophthalazinediones, horseradish peroxidase, alkaline phosphatase, lysozyme, and glucose-6-phosphate dehydrogenase. The antibodies may be tagged with such labels by known methods. For instance, coupling agents such as aldehydes, carbodiimides, dimaleimide, imidates, succinimides, bis-diazotized benzadine and the like may be used to tag the antibodies with the above-described fluorescent, chemiluminescent, and enzyme labels. The antibodies may also be labeled with magnetic beads for use in magnetic sorting regimens.

The MAb's of the present invention encompass chimeric MAbs, including, "humanized" forms of non-human (*e.g.*, murine) MAbs. Humanized MAbs are chimeric antibodies which contain minimal sequence derived from non-human immunoglobulin. For the most part, humanized antibodies are human immunoglobulins (recipient antibody) in which residues from a hypervariable region of the recipient are replaced by residues from a hypervariable region of a non-human species (donor antibody) such as mouse, rat, rabbit or nonhuman primate having the desired specificity, affinity, and capacity. In some instances, framework residues of the human immunoglobulin are replaced by corresponding non-human residues. Furthermore, humanized antibodies may comprise residues which are not found in the recipient antibody or in the donor antibody. These modifications are made to further refine antibody performance. In general, the humanized antibody will comprise substantially all of at least one, and typically two, variable domains, in which all or substantially all of the hypervariable regions correspond to those of a non-human immunoglobulin and all or substantially all of the framework regions are those of a human immunoglobulin sequence. The humanized antibody optionally also will comprise at least a portion of an immunoglobulin constant region (FC), typically that of a human immunoglobulin (*see* Jones *et al.*, 1986; Riechmann *et al.*, 1988; and Presta, 1992). Fully human MAbs are preferred in the therapeutic methods of the present invention.

"Single-chain FV' or "sFv" antibody fragments of the present invention comprise the VH and VL domains of antibody, wherein these domains are present in a single polypeptide chain. Generally, the Fv polypeptide further comprises a polypeptide linker between the VH and VL domains that enables the sFv to form the desired structure for antigen binding (*see* Pluckthun, 1994).

Aspects of the present invention include methods to inhibit dermcidin-mediated signaling events that lead to inhibition of tumor cell proliferation and induction of tumor cell apoptosis, and sensitization of tumor cells to chemotherapeutic agents, comprising delivering an anti-dermcidin antibody to a cell that expresses MUC1.

IV. Aptamers

Aptamers are specific nucleic acid sequences that bind to a wide array of target molecules with high affinity and specificity. They may be developed by a method commonly known as "*in vitro* selection" (Ellington *et al.*, 1990), "*in vitro* evolution" (Joyce, Gene 1989, or "SELEX" (Selective Evolution of Ligands by Evolution; Tuerk *et al.*, 1990). Each SELEX-identified nucleic acid ligand is a specific ligand of a given target compound or molecule. The SELEX process is based on the observation that nucleic acids have sufficient capacity for forming a variety of two- and three-dimensional structures and sufficient chemical versatility available within their monomers to act as ligands (form specific binding pairs) with virtually any chemical compound, whether monomeric or polymeric. Molecules of any size or composition can serve as targets. The SELEX method applied to the application of high affinity binding involves selection from a mixture of candidate oligonucleotides and step-wise iterations of binding, partitioning and amplification, using the same general selection scheme, to achieve virtually any desired criterion of binding affinity and selectivity. Starting from a mixture of nucleic acids, preferably comprising a segment of randomized sequence, the SELEX method includes steps of contacting the mixture with the target under conditions favorable for binding, partitioning unbound nucleic acids from those nucleic acids which have bound specifically to target molecules, dissociating the nucleic acid-target complexes, amplifying the nucleic acids dissociated from the nucleic acid-target complexes to yield a ligand enriched mixture of nucleic acids, then reiterating the steps of binding, partitioning, dissociating and amplifying through as many cycles as desired to yield highly specific high affinity nucleic acid ligands to the target molecule. Thus, this method allows for the screening of large random pools of nucleic acid molecules for a particular functionality, such as binding to small organic molecules (Famulok *et al.*, 1994; Connell *et al.*, 1994; Ellington *et al.*, 1990), and proteins (Jellinek *et al.*, 1993; Tuerk

et al., 1992; Tuerk *et al.*, 1993; Schneider *et al.*, 1992). The SELEX process is also described in U.S. Patent 5,475,096 and U.S. Patent 5,270,163, both incorporated herein by reference in their entirety.

The SELEX method also encompasses the identification of high-affinity nucleic acid ligands containing modified nucleotides conferring improved characteristics on the ligand, such as improved *in vivo* stability or improved delivery characteristics. Examples of such modifications include chemical substitutions at the ribose and/or phosphate and/or base positions. SELEX process-identified nucleic acid ligands containing modified nucleotides are described in U.S. Patent 5,660,985 and U.S. Patent 5,580,737 (both herein incorporated by reference) describes highly specific nucleic acid ligands containing one or more nucleotides modified with 2'-amino, 2'-fluoro, and/or 2'-O-methyl. The SELEX method encompasses combining selected oligonucleotides with other selected oligonucleotides and non-oligonucleotide functional units as described in U.S. Patent 5,637,459 and U.S. Patent 5,683,867 (both herein incorporated by reference). These applications allow the combination of the broad array of shapes and other properties, and the efficient amplification and replication properties, of oligonucleotides with the desirable properties of other molecules.

Also encompassed by the present invention are so called Spiegelmers, mirror image aptamers composed of L-ribose or L-2'deoxyribose units. The chiral inversion results in an improved plasma stability compared with natural D-oligonucleotide aptamers. Using in vitro selection, an oligonucelotide that binds to the synthetic enantiomer of a target molecule, *e.g.*, a D-peptide, is isolated. The selected apatmer is then resynthesiazed in the L-configuration and this Spiegelmer (from the German "speigel" for mirror) will bind to the physiological target with the same affinity and specificity as the aptamer to the mirror-image target. This stratgey has been used to identify L-oilogonucelotide ligands to a number of targets including gonadotropin-releasing hormone, vasopressin, arginine and adenosine (Leva *et al.*, 2002; Wlotzka *et al.*, 2002; Klussmann *et al.*, 1996; Nolte *et al.*, 1996; Williams *et al.*, 1997, all herein incorporated by reference).

Aptamers of the present invention include those directed towards a recognition site within the amino acid sequence of dermcidin (SEQ ID NO: 43), and in some embodiments towards a recognition site within the amino acid sequence of the mature polypeptide, residues 20 to 110 of SEQ ID NO: 43, and in a preferred embodiment to a recognition site within amino acid residues 20 to 49 of SEQ ID NO: 43. In other embodiments, the aptamer of the present invention is directed towards a recognition site within amino acid residues 20 to 30, or within

amino acid residues 25 to 35, or within amino acid residues 30 to 40, or within amino acid residues 45 to 55, of SEQ ID NO: 43.

Aspects of the present invention include methods to inhibit dermcidin expression, inhibition of dermcidin-mediated signaling events that lead to inhibition of tumor cell proliferation and induction of tumor cell apoptosis, and sensitization of tumor cells to chemotherapeutic agents, comprising delivering an apatmer directed towards a recognition site within the dermicidin sequence to a MUC1-expressing cell.

V. Antisense Oligonucleotides and Interfering RNA

The present invention also employs antisense compounds, particularly oilgonucleotides, for use in modulating the function of nucleic acid molecules encoding MUC1 ligands, such as dermcidin. Antisense methodology takes advantage of the fact that nucleic acids tend to pair with "complementary sequences." By complementary, it is meant that polynucleotides are those capable of base-pairing according to the standard Watson-Crick complementary rules. The oligonucleotides of the present invention may be targeted wholly or in part to informational sequences, *i.e.*, those coding for a protein, and other associated ribonucleotides such 5'-untranslated regions, 3'-untranslated regions, 5' cap regions and intron/exon junctions. Thus, the invention provides oilgonucleotides which specifically hybridize with nucleic acids, preferably mRNA, encoding MUC1 ligands such as dermcidin. The overall effect of interference with mRNA is modulation of expression of dermcidin. Such modulation can be measured in ways that are routine in the art. In addition, effects on cancer cell proliferation, tumor growth and sensitization of cancer cells to other chemotherapeutic agents can be assessed.

It is understood that an oligonucleotide need not be 100% complementary to its target nucleic acid sequence to be specifically hybridizable. An oligonucleotide is specifically hybridizable when binding of the oligonucleotide to the target interferes with the normal function of the target molecule to cause a loss of utility, and there is a sufficient degree of complementarity to avoid non-specific binding of the oligonucleotide to non-target sequences under conditions in which specific binding is desired, *i.e.*, under physiological conditions in the case of *in vivo* assays or therapeutic treatment.

The antisense compounds in accordance with this invention preferably comprise from about 4 to about 50 nucleobases. Particularly preferred are antisense oligonucleotides comprising from about 8 to about 30 linked nucleobases. The oligonucleotides used in accordance with this invention may be conveniently and routinely made through the well-known technique of solid phase synthesis.

The terms "specifically hybridizable" and "complementary" are used to indicate a degree of complementarity sufficient to result in stable and specific binding between the antisense oligonucleotide and the target nucleic acid sequence.

An oligonucleotide need not be 100% complementary to its target nucleic acid sequence to be specifically hybridizable. An oligonucleotide considered "specifically hybridizable" when binding of the oligonucleotide to the target interferes with the normal function of the target molecule to cause a loss of utility and decrease in expression of the product protein, and there is a sufficient degree of complementarity to avoid non-specific binding of the oligonucleotide to non-target sequences.

Demcidin is expressed as a 110 amino acid precursor (SEQ ID NO: 43), the mature polypeptide being formed by clevage of 19 amino acid residue signal peptide. The sequences coding for the first 110 amino acid precursor is provided in SEQ ID NO: 44.

In some embodiments, the antisense oligonucleotide comprises a sequence of at least 4 nucleotides that is complementary to a region os SEQ ID NO: 44. In another embodiment the antisense oligonucleotide is at least 8 nucleotides that is complementary to a region of SEQ ID NO: 44.

The present invention also encompasses expression vectors comprising an expression control system that directs production of a transcript of the foregoing antisense oilgonucleotides. In addition, the present invention provides for methods of hybridization comprising providing one of the forgoing antisense oilgonucleotides and contacting such oligonucleotide with a nucleic acid comprising the target sequence under conditions that permit hybridization of the oligonucleotide with the nucleic acid. Also included are methods of inhibiting translation of mRNA comprising providing one of the forgoing antisense oilgonucleotides and providing a cell comprising mRNA comprising the target sequence and introducing the oligonucleotide into the cell, wherein the oligonucleotide inhibits translation of the mRNA in the cell.

The present invention also encompasses the use of RNA interference ("RNAi") molecules, including small interfering RNA ("siRNA") molecules, as a method of MUC1 gene silencing. siRNA's for mammalian systems are typically composed of double-stranded RNA with 19 to 28, preferable 19 to 23, nucleotide RNA strands, a 2 nucleotide overhand at the 3' end and an optional 5' phosphate group (Yang *et al.*, 2001; Elbashir *et al.*, 2002). Such siRNA's provide a highly active and selective method for reducing the expression of targeted genes by utilizing the RNA interference post-translational gene silencing pathway. Interference of gene expression by interfering RNA is recognized as a naturally occurring mechanism for silencing alleles during development in plants, invertebrates and vertebrates. In this pathway, it is

believed that siRNA form a protein complex, sometimes termed an "RNA-induced silencing complexes" ("RISC"), that serve to guide a nucleoside to the mRNA whose sequence matches that of the siRNA, resulting in cleavage of that mRNA (Zamore, 2001). Studies on a variety of gene products of different functions and subcellular localizations have demonstrated the general applicability of the siRNA technique of gene silencing (Harborth *et al.*, 2001).

In some embodiments, double-stranded siRNA complexes are designed using the following guidelines:

(1) a double-stranded RNA complex is composed of a 21-nucleotide sense and 21-nucleotide anti-sense strand, both with a 2-nucleotide 3' overhang, *i.e.*, a 19 nucleotide complementary region;

(2) a 23 nucleotide sequence is chosen in the coding region of the mRNA with a G:C ratio as close to 50% as possible, preferably within about 60% to about 40%, or alternatively within about 70% to about 30% (to create a 21 base pair duplex with overhangs that match the target sequence and have a 19 base pair complementary region, a target sequence of 23 base pairs is needed);

(3) preferably avoid regions within about 75 nucleotides of the AUG start codon or within about 75 nucleotides of the termination codon;

(4) preferably avoid more than three guanosines in a row as poly G sequences can hyperstack and agglomerate;

(5) preferably choose a sequence that starts with AA as this results in siRNA's with dTdT overhangs that are potentially more resistant to nucleases;

(6) preferably the sequence is not homologous to other genes to prevent silencing of unwanted genes with a similar sequence.

A negative control may be included, such a negative control being a nucleotide sequence from a database for a non-exisiting gene.

Examples of such 21 nucleotide target DNA sequences are provided in SEQ ID NO: 45 through SEQ ID NO: 69.

Also encompassed by the present invention are double-stranded RNA complexes wherein the antisense strand is not exactly complementary to the target mRNA sequence, but can still downregulate MUC-1 ligand expression. Thus, in some embodiments, the antisense strand is a sequence that will hybridize under stringent conditions to the target mRNA sequence. Stringent conditions as used herein means hybridization to filter-bound DNA in 0.5 M $NaHPO_4$, 7% sodium dodecyl sulfate (SDS), 1 mM EDTA at 65°C, and washing in 0.1x sodium chloride/sodium citrate (SSC)/0.1% SDS at 68°C (Ausubel *et al.*, eds., 1989, Current Protocols in

Molecular Biology, Vol. I, John Wiley & Sons, Inc., New York, at p. 2.10.3). In other embodiments, the antisense strand is a sequence that is substantially complementary to the target mRNA sequence. Substantially complementary means that the sequence has up to four mismatched base pairs with the caveat that the double-stranded RNA complex can still effect the downregulation of MUC1 ligands. Downregulation of a MUC1 ligand is determined by inhibition in protein expression by Western blot analysis using specific anti-MUC1 ligand antibodies and/or a RT-PCR analysis specific for MUC1 ligand RNA as compared to a suitable control. In other embodiments, the sense strand has at least a 60% sequence identity to the target mRNA sequence, with the caveat that that the double-stranded RNA complex can still effect the downregulation of the MUC1 ligand. The extent of sequence identity may be greater than 60%, such as at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, or at least 90% sequence identity. "Sequence identity" as used herein, refers to the subunit sequence similarity of two polymeric molecules, herein oligonucleotides. The identity between two sequences is a direct function of the numbering of matching or identical positions. Identity can be measured using the sequence analysis softwear BLASTN. The default parameters for comparing two sequences by BLASTN are reward for match = 1, penalty for mismatch = -2, open gap = 5, extension gap = 2.

The double-standed siRNA complexes of the present invention also encompass hair-pin RNA, in which both strands of a siRNA duplex is included within a single RNA oligonucelotide (Yu *et al.*, 2002; Devroe *et al.*, 2002; Brummelkamp *et al.*, 2002). Thus, for example, the forgoing exemplified complementary sense and antisense RNA sequences may be incorporated into single hairpin RNA oligonulceotides.

In addition to the use of double-stranded siRNA complexes, single strand antisense RNA oilgonucelotides can also result in gene silencing utilizing the interference pathway (Martinez *et al.*, 2002). Such single strand antisense RNA is preferably 5' phosphorylated and in mammalian systems is effective from 17 to at least 29 nucleotides in length (Martinez *et al.*, 2002) and in *C. elegans* from between 22 and 40 nucleotides in length (Tijsterman *et al.*, 2002). Thus, one aspect of the present invention is a 5' phosphorylated RNA olignucleotide of 17 to 40 bases that will hybridize under stringent conditions to SEQ ID NO: 44. Stringent conditions for hydriziation are as defined above. Another aspect of the present invention are 5' phosphorylated RNA olignucleotides of 17 to 40 bases, wherein the sequences are substantially complementary to a sequence of an equivalent number of bases found in SEQ ID NO: 44, and wherein the oligonucleotide will downregulate the MUC1 ligand of interest. Substantially complementary means that the antisense sequence of the double-stranded siRNA complex has up to four

mismatched base pairs as compared with the target mRNA sequence, with the caveat that the 5' phosphorylated RNA oligonucleotide of 17 to 40 bases can still effect the downregulation of the MUC1 ligand. Another aspect of the invention are 5' phosphorylated RNA oligonucleotide of 17 to 40 bases, wherein the sequences have at least a 60 % sequence identity to a sequence of an equivalent number of bases in SEQ ID NO: 44, the antisense sequence complementary to the coding region of MUC1 ligand mRNA, and wherein the oligonucleotide will downregulate MUC1 ligand expression.

Aspects of the present invention include methods to inhibit dermcidin expression, inhibition of dermcidin-mediated signaling events that lead to inhibition of tumor cell proliferation and induction of tumor cell apoptosis, and sensitization of tumor cells to chemotherapeutic agents, comprising delivering an antisense RNA of the present invention into a cell that expresses dermcidin.

siRNA oilgonucelotides can be synthesized, annealed when required, and purified by methods known in the art (*see e.g.*, Elbashir *et al.*, 2002, herein incorporated by reference). Cells may be transfected with siRNA by use of liposomal and other lipid-mediated transfection methodologies (Hohjoh, 2002; Bertrand *et al.*, 2002; Elbashir *et al.*, 2002, all herein incorporated by reference). Alternatively, siRNA's may be expressed in cells transfected with suitable expression cassettes or vectors (Brummelkamp *et al.*, 2002; Sui *et al.*, 2002; Paul *et al.*, 2002) and by the use of viral mediated delivery mechanisms, *e.g.*, adenoviral and retroviral systems, that may be suitably used to express siRNA *in vitro* and *in vivo* (Xia *et al.*, 2002; Devroe & Silver, 2002). In addition to delivery of siRNA molecules, the present invention also encompasses the delivery of longer RNAi molecules by expression constructs. These longer RNAi molecules may effect gene silencing directly or subsequent to enzymatic cleavage by Dicer. The longer RNAi molecule may be a dsRNA molecule wherein the sense is SEQ ID NO: 42 or a fragment thereof, or in one embodiment is a dsRNA molecule of substantially equivalent size of a dsRNA molecule wherein the sense is SEQ ID NO: 42, wherein substantially similar means ± 10% relative to the number of bp in the aforementioned dsRNA molecules wherein the sense is SEQ ID NO: 42, wherein the antisense strand will hybdirize with SEQ ID 42 under stringent conditions, as defined previously, or in another embodiment are substantially complementary, as defined previously, to SEQ ID 42, or in another embodiment the sense strand has at least 60% sequence identity, as previously defined, to SEQ ID NO 42. In various embodiments, The extent of sequence identity may be greater than 60%, such as at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, or at least 90% sequence identity. In other embodiments, the longer the antisense strand of a dsRNAi molecule may comprise one or more

of the the sequences SEQ ID NO: 76 though SEQ ID NO: 104, wherein the dsRNAi molecule is about 100 bp, or about 150 bp, or about 200 bp, or about 250 bp, or about 300 bp, or about 350 bp, or about 400 bp in length.

In the context of the present invention, the term "oligonucleotide" refers to an oligomer or polymer of ribonucleic acid or deoxyribonucleic acid. This term includes oligonucleotides composed of naturally-occurring nucleobases, sugars and covalent intersugar (backbone) linkages as well as oligonucleotides having non-naturally-occurring portions which function similarly. Such modified or substituted oligonucleotides are often preferred over native forms because of desirable properties such as, for example, enhanced cellular uptake, enhanced binding to target and increased stability in the presence of nucleases.

In some embodiments, the oilgonucleotides of the present invention may comprise one or more modified internucleoside linkage. Modifications of the normal 3' to 5' phosphodiester linkage include phosphorothioates, chiral phosphorothioates, phosphorodithioates, phosphotriesters, aminoalkylphosphotriesters, methyl and other alkyl phosphonates including 3'-alkylene phosphonates, 5'-alkylene phosphonates and chiral phosphonates, phosphinates, phosphoramidates including 3'-amino phosphoramidate and aminoalkylphosphoramidates, thionophosphoramidates, thionoalkylphosphonates, thionoalkylphosphotriesters, selenophosphates and boranophosphates having normal 3'-5' linkages, 2'-5' linked analogs of these, and those having inverted polarity wherein one or more internucleotide linkages is a 3' to 3', 5' to 5' or 2' to 2' linkage. Examples of foregoing are taught in WO9905160 and U.S. Patents 3,687,808; 4,469,863; 4,476,301; 5,023,243; 5,177,196; 5,188,897; 5,264,423; 5,276,019; 5,278,302; 5,286,717; 5,321,131; 5,399,676; 5,405,939; 5,453,496; 5,455,233; 5,466,677; 5,476,925; 5,519,126; 5,536,821; 5,541,306; 5,550,111; 5,563,253; 5,571,799; 5,587,361; 5,194,599; 5,565,555; 5,527,899; 5,721,218; 5,672,697, 5,625,050, 5,652,355, 5,652,356 and 5,750,674, all of which are herein incorporated by reference.

Other non-phosphorus containing modified linkages include those formed by short chain alkyl or cycloalkyl internucleoside linkages, mixed heteroatom and alkyl or cycloalkyl internucleoside linkages, or one or more short chain heteroatomic or heterocyclic internucleoside linkages. Examples include morpholino, siloxane, sulfide, sulfoxide, sulfone, sulfonate, sulfonamide, formacetyl, thioformacetyl, riboacetyl, alkene, sulfamate, methyleneimino, methylenehydrazino, amide backbones; and others having mixed N, O, S, and methylene parts. Examples of foregoing are taught in U.S. Patents 5,034,506; 5,166,315; 5,185,444; 5,214,134; 5,216,141; 5,235,033; 5,264,562; 5,264,564; 5,405,938; 5,434,257; 5,466,677; 5,470,967; 5,489,677; 5,541,307; 5,561,225; 5,596,086; 5,602,240; 5,610,289; 5,602,240; 5,608,046;

5,610,289; 5,618,704; 5,623,070; 5,663,312; 5,633,360; 5,677,437; 5,792,608; 5,646,269 and 5,677,439, all of which are herein incorporated by reference.

In other embodiments, the oilgonucleotides of the present invention may comprise one or more modified sugars, including substituted sugars and sugar mimetics. Examples of 2' substitutents include OH, halo, amino, cyano, or O, S or N linked alkyl, alkenyl or alkynyl groups, wherein the alkyl, alkenyl and alkynyl groups may be substituted or unsubstituted C_1-C_{10} alkyl or C_2-C_{10} alkenyl and alkynyl, or, alkoxyalkoxy, heterocycloalkyl, heterocycloalkaryl, aminoalkylamino, polyalkylamino, or substituted silyl. Examples include 2'-dimethylaminooxyethoxy, 2'-dimethylaminoethoxyethoxy, 2'-methoxy, 2'-aminopropoxy, 2'-CH_2-CH=CH_2, 2'-O- CH_2-CH=CH_2, and 2'-fluoro. The 2'-modification may be in the arabino position or ribo position. Substitutions at the 2' site of sugars also include Locked Nucleic Acids (LNAs) wherein the 2'-hydroxyl group is linked to the 3' or 4' carbon atom of the sugar ring thereby forming a bicyclic sugar moiety. In one embodiment a -CH_2- or -CH_2CH_2- group bridges the 2' oxygen atom and the 4' carbon atom. Similar modifications may also be made at the 3' position of the sugar on the 3' terminal nucleotide or in 2'-5' linked oligonucleotides and the 5' position of 5' terminal nucleotide. Oligonucleotides may also have sugar mimetics such as cyclobutyl moieties in place of the pentofuranosyl sugar. Examples of foregoing are taught in U.S. Patents 4,981,957; 5,118,800; 5,319,080; 5,359,044; 5,393,878; 5,446,137; 5,466,786; 5,514,785; 5,519,134; 5,567,811; 5,576,427; 5,591,722; 5,597,909; 5,610,300; 5,627,053; 5,639,873; 5,646,265; 5,658,873; 5,670,633; 5,792,747; 5,700,920, and 6268490 and U.S. Application No. 20020068708A1, all of which are herein incorporated by reference.

In some embodiments, both the sugar and the internucleoside linkages are modified or replaced with novel groups. One such example is referred to as a peptide nucleic acid (PNA) wherein the sugar-backbone of an oligonucleotide is replaced with an amide containing backbone, in particular an aminoethylglycine backbone. The nucleobases are retained and are bound directly or indirectly to aza nitrogen atoms of the amide portion of the backbone. Examples of foregoing are taught in U.S. Patents 5,539,082; 5,714,331; 5,719,262, and 6,395,474, all of which are herein incorporated by reference.

In further embodiments, the oilgonucleotides of the present invention may comprise one or more modified nucleobase. As used in the context of the oligonucelotides of the present invention, "unmodified" nucleobases include the purine bases adenine and guanine, and the pyrimidine bases thymine, cytosine and uracil. Modified nucleobases include other synthetic and natural occurring nucleobases such as 2,6-diamonopurine, 5-methylcytosine, 5-hydroxymethyl cytosine, xanthine, hypoxanthine, 2-aminoadenine, 6-methyl and other alkyl

derivatives of adenine and guanine, 2-propyl and other alkyl derivatives of adenine and guanine, 2-thiouracil, 2-thiothymine and 2-thiocytosine, 5-halouracil and cytosine, 5-propynyl uracil and cytosine and other alkynyl derivatives of pyrimidine bases, 6-azo uracil, cytosine and thymine, 5-uracil (pseudouracil), 4-thiouracil, 8-halo, 8-amino, 8-thiol, 8-thioalkyl, 8-hydroxyl and other 8-substituted adenines and guanines, 5-halo particularly 5-bromo, 5-trifluoromethyl and other 5-substituted uracils and cytosines, 7-methylguanine and 7-methyladenine, 2-fluoro-adenine, 2-amino-adenine, 8-azaguanine and 8-azaadenine, 7-deazaguanine and 7-deazaadenine and 3-deazaguanine and 3-deazaadenine. Other examples include tricyclic pyrimidines such as phenoxazine cytidine, phenothiazine cytidine, phenoxazine cytidine, carbazole cytidine, and pyridoindole cytidine. Modified nucleobases may also include those in which the purine or pyrimidine base is replaced with other heterocycles, for example 7-deaza-adenine, 7-deazaguanosine, 2-aminopyridine and 2-pyridone. Examples of foregoing are taught in U.S. Patents 3,687,808, 4,845,205; 5,130,302; 5,134,066; 5,175,273; 5,367,066; 5,432,272; 5,457,187; 5,459,255; 5,484,908; 5,502,177; 5,525,711; 5,552,540; 5,587,469; 5,594,121, 5,596,091; 5,614,617; 5,645,985; 5,830,653; 5,763,588; 5,681,941; 5,750,692, 6,005,096; 6414112 and Englisch *et al.*, Angewandte Chemie, International Edition, 1991, 30, 613, and Sanghvi, Y. S., Chapter 15, Antisense Research and Applications, pages 289-302, Crooke, S. T. and Lebleu, B. ed., CRC Press, 1993, all of which are herein incorporated by reference.

In still further embodiments, the oligonucleotides of the present invention may be linked to one or more moieties or conjugates which enhance the activity, tissue distribution, and/or cellular uptake of the oligonucleotides. Such moieties include but are not limited to, N-9-2-hydroxypropyl)methacrylamide copolymer (Jensen *et al.*, 2002) cholesterol (Letsinger, 1989), cholic acid (Manoharan *et al.*, 1994), a thioether, (Manoharan *et al.*, 1992; Manoharan *et al.*, 1993), a thiocholesterol (Oberhauser *et al.*, 1992), an aliphatic chain, such as dodecandiol or undecyl residues (Saison-Behmoaras *et al.*, 1991; Kabanov *et al.*, 1990; Svinarchuk *et al.*, 1993), a phospholipid, *e.g.*, di-hexadecyl-rac-glycerol or triethyl-ammonium 1,2-di-O-hexadecyl-rac-glycero-3-H-phosphonate (Manoharan *et al.*, 1995; Shea *et al.*, 1990), a polyamine or a polyethylene glycol chain (Manoharan *et al.*, 1995), or adamantane acetic acid (Manoharan *et al.*, 1995), a palmityl moiety (Mishra *et al.*, 1995), or an octadecylamine or hexylamino-carbonyl-oxycholesterol moiety (Crooke *et al.*, 1996) or peptides including delivery peptides, *e.g.*, Antennapaedia peptide (Fischer *et al.*, 2002; Zatsepin *et al.*, 2002; Oehlke *et al.*, 2002). Further examples that teach the preparation of such oligonucleotide conjugates include U.S. Patents 4,828,979; 4,948,882; 5,218,105; 5,525,465; 5,541,313; 5,545,730; 5,552,538; 5,578,717, 5,580,731; 5,580,731; 5,591,584; 5,109,124; 5,118,802; 5,138,045; 5,414,077;

5,486,603; 5,512,439; 5,578,718; 5,608,046; 4,587,044; 4,605,735; 4,667,025; 4,762,779; 4,789,737; 4,824,941; 4,835,263; 4,876,335; 4,904,582; 4,958,013; 5,082,830; 5,112,963; 5,214,136; 5,082,830; 5,112,963; 5,214,136; 5,245,022; 5,254,469; 5,258,506; 5,262,536; 5,272,250; 5,292,873; 5,317,098; 5,371,241, 5,391,723; 5,416,203, 5,451,463; 5,510,475; 5,512,667; 5,514,785; 5,565,552; 5,567,810; 5,574,142; 5,585,481; 5,587,371; 5,595,726; 5,597,696; 5,599,923; 5,599,928 and 5,688,941, all of which are herein incorporated by reference.

Another aspect of the present invention provides for pharmaceutical compositions comprising an oligonucleotide of the present invention and a pharmaceutically acceptable carrier.

VI. Formulations

For pharmaceutical use, the polypeptides of the present invention are formulated for parenteral, nasal inhalation, particularly intravenous or subcutaneous, delivery according to conventional methods. Intravenous administration will be by bolus injection or infusion over a typical period of one to several hours. In general, pharmaceutical formulations will include an antibody in combination with a pharmaceutically acceptable vehicle, such as saline, buffered saline, 5% dextrose in water or the like. Formulations may further include one or more excipients, preservatives, solubilizers, buffering agents, albumin to prevent protein loss on vial surfaces, *etc.* Methods of formulation are well known in the art and are disclosed, for example, in Remington's Pharmaceutical Sciences, Gennaro, ed., Mack Publishing Co., Easton Pa., 1990, which is incorporated herein by reference.

VII. Treatment Methods

Tumors that can be suitably treated with the therapeutic polypeptides or other agents of the present invention include tumors expressing MUC1. Such tumors include, but are not limited to, tumors of the brain (glioblastomas, medulloblastoma, astrocytoma, oligodendroglioma, ependymomas), lung, liver, spleen, kidney, lymph node, small intestine, pancreas, blood cells, colon, stomach, breast, endometrium, prostate, testicle, ovary, skin, head and neck, esophagus, bone marrow, blood and other tissue. The tumor may be distinguished as metastatic and non-metastatic. Pre-malignant lesions may also be suitably treated with the methods of the present invention.

The treatment with MUC1-EC chimeric proteins or other agents of the present invention may precede or follow irradiation and/or chemotherapy by intervals ranging from seconds to weeks and/or be administered concurrently with such treatments. In embodiments where the

MUC1-EC chimeric proteins or other agents of the present invention and irradiation and/or chemotherapy are applied separately to the cell, steps should be taken to ensure that a significant period of time does not expire between the time of each delivery, such that the combination of the two or three treatments would still be able to exert an advantageously combined effect on the cell. In such instances, it is contemplated that one would contact the cell with the treatment agents or modalities within amount 0.1 to 25 h of each other and, more preferably, within about 1 to 4 h of each other, with a delay time of only about 1 h to about 2 h being most preferred. In some situations, it is desirable to extend the time period of treatment significantly, however, where several days (2, 3, 4, 5, 6 or 7) or several weeks (1, 2, 3, 4, 5, 6, 7 or 8) lapse between the respective administrations. In any case, the invention contemplates that the MUC1-EC chimeric proteins may be given before, after or even simultaneously with the ionizing radiation and/or chemotherapeutic agent.

Treatment comprises administration of a therapeutically effective dose. In the practice of any of the methods of the invention, or preparation of any of the pharmaceutical compositions, a "therapeutically effective amount" is an amount of antibody which is capable of binding to an antigen associated with the condition to be treated. Accordingly, the effective amount will vary with the subject being treated, as well as the condition to be treated. Determination of dose is within the level of ordinary skill in the art. The antibodies may be administered for acute treatment, over one week or less, often over a period of one to three days or may be used in chronic treatment, over several months or years.

In the present invention, the term “ionizing radiation” means radiation comprising particles or photons that have sufficient energy or can produce sufficient energy *via* nuclear interactions to produce ionization (gain or loss of electrons). An exemplary and preferred ionizing radiation is an x-radiation. Means for delivering x-radiation to a target tissue or cell are well known in the art. The amount of ionizing radiation needed in a given cell generally depends on the nature of that cell. Means for determining an effective amount of radiation are well known in the art. Used herein, the term “an effective dose” of ionizing radiation means a dose of ionizing radiation that produces cell damage or death when given in conjunction with MUC1-EC chimeric proteins or other agents of the present invention, optionally further combined with a chemotherapeutic agent.

Dosage ranges for x-rays range from daily doses of 50 to 200 roentgens for prolonged periods of time (3 to 4 weeks), to single doses of 2000 to 6000 roentgens. Dosage ranges for radioisotopes vary widely, and depend on the half-life of the isotope, the strength and type of radiation emitted, and the uptake by the neoplastic cells.

Any suitable means for delivering radiation to a tissue may be employed in the present invention, in addition to external means. For example, radiation may be delivered by first providing a radiolabeled antibody that immunoreacts with an antigen of the tumor, followed by delivering an effective amount of the radiolabeled antibody to the tumor. In addition, radioisotopes may be used to deliver ionizing radiation to a tissue or cell.

The present invention encompasses the use of MUC1-EC chimeric proteins in combination with chemotherapeutic agents. The chemotherapeutic agents useful in the methods of the invention include the full spectrum of compositions and compounds that are known to be active in killing and/or inhibiting the growth of cancer cells. The chemotherapeutic agents, grouped by mechanism of action include DNA-interactive agents, antimetabolites, tubulin interactive agents, anti-hormonals, anti-virals, ornithine decarboxylase ("ODC") inhibitors and other cytotoxics such as hydroxyurea. Any of these agents are suitable for use in the methods of the present invention.

DNA-interactive agents include the alkylating agents, *e.g.*, cisplatin, cyclophosphamide; the DNA strand-breakage agents, such as bleomycin; the intercalating topoisomerase II inhibitors, *e.g.*, dactinomycin and doxorubicin; the nonintercalating topoisomerase II inhibitors such as, etoposide and teniposide; and the DNA minor groove binder, plicamycin.

The alkylating agents form covalent chemical adducts with cellular DNA, RNA and protein molecules and with smaller amino acids, glutathione and similar chemicals. Generally, these alkylating agents react with a nucleophilic atom in a cellular constituent, such as an amino, carboxyl, phosphate, sulfhydryl group in nucleic acids, proteins, amino acids, or glutathione. The mechanism and the role of these alkylating agents in cancer therapy is not well understood. Typical alkylating agents include: nitrogen mustards, such as chlorambucil, cyclophosphamide, ifosfamide, mechlorethamine, melphalan, uracil mustard; aziridine such as thiotepa; methanesulphonate esters such as busulfan; nitroso ureas, such as carmustine, lomustine, streptozocin; platinum complexes such as cisplatin, carboplatin; bioreductive alkylators, such as mitomycin and procarbazine, dacarbazine and altretemine; DNA strand-breaking agents including bleomycin.

Topoisomerases are ubiquitous cellular enzymes which initiate transient DNA strand breaks during replication to allow for free rotation of the strands. The functionality of these enzymes is critical to the replication process of DNA. Without them, the torsional strain in the DNA helix prohibits free rotation, the DNA strands are unable to separate properly, and the cell eventually dies without dividing. Topo I links to the 3'-terminus of a DNA single strand break, while Topo II links to the 5'-terminus of a double strand DNA break. DNA topoisomerase II

inhibitors include the following: intercalators such as amsacrine, dactinomycin, daunorubicin, doxorubicin, idarubicin and mitoxantrone; nonintercalators such as etoposide and teniposide; camptothecins including irinotecan (CPT-II) and topotecan. A representative DNA minor groove binder is plicamycin.

The antimetabolites generally exert cytotoxic activity by interfering with the production of nucleic acids by one or the other of two major mechanisms. Some of the drugs inhibit production of the deoxyribonucleoside triphosphates that are the immediate precursors of DNA synthesis, thus inhibiting DNA replication. Some of the compounds are sufficiently like purines or pyrimidines to be able to substitute for them in the anabolic nucleotide pathways. These analogs can then be substituted into the DNA and RNA instead of their normal counterparts. The antimetabolites useful herein include: folate antagonists such as methotrexate and trimetrexate; pyrimidine antagonists such as fluorouracil, fluorodeoxyuridine, azacitidine, cytarabine, and floxuridine; purine antagonists include mercaptopurine, 6-thioguanine, fludarabine, pentostatin; sugar modified analogs include cytarabine, fludarabine; ribonucleotide reductase inhibitors include hydroxyurea.

Tubulin interactive agents interfere with cell division by binding to specific sites on Tubulin, a protein that polymerizes to form cellular microtubules. Microtubules are critical cell structure units. When the interactive agents bind on the protein; the cell cannot properly form microtubules. Tubulin interactive agents include vincristine and vinblastine, both alkaloids and the taxanes (paclitaxel and docetaxel).

Although their mechanisms of action are different, both taxanes and vinca alkaloids exert their biological effects on the cell microtubles. Taxanes act to promote the polymerization of tubulin, a protein subunit of spindle microtubles. The end result is the inhibition of depolymerization of the microtubles, which causes the formation of stable and nonfunctional microtubles. This disrupts the dynamic equilibrium within the microtuble system, and arrests the cell cycle in the late G_2 and M phases, which inhibits cell replication.

Like taxanes, vinca alkaloids also act to affect the microtuble system within the cells. In contrast to taxanes, vinca alkaloids bind to tubulin and inhibit or prevent the polymerization of tubulin subunits into microtubles. Vinca alkaloids also induce the depolymerization of microtubles, which inhibits microtuble assembly and mediates cellular metaphase arrest. Vinca alkaloids also exert effects on nucleic acid and protein synthesis; amino acid, cyclic AMP, and glutathione synthesis; cellular respiration; and exert immunosuppressive activity at higher concentrations.

Antihormonal agents exert cytotoxic activity by blocking hormone action at the end-receptor organ. Several different types of neoplasm require hormonal stimulation to propagate cell reproduction. The antihormonal agents, by blocking hormone action, deprive the neoplastic cells of a necessary stimulus to reproduce. As the cells reach the end of their life cycle, they die normally, without dividing and producing additional malignant cells. Antihormonal agents are typically derived from natural sources and include: estrogens, conjugated estrogens and ethinyl estradiol and diethylstibesterol, chlortrianisen and idenestrol; progestins such as hydroxyprogesterone caproate, medroxyprogesterone, and megestrol; androgens such as testosterone, testosterone propionate; fluoxymesterone, methyltestosterone.

Adrenal corticosteroids are derived from natural adrenal cortisol or hydrocortisone. They are used because of their anti-inflammatory benefits as well as the ability of some to inhibit mitotic divisions and to halt DNA synthesis. These compounds include prednisone, dexamethasone, methylprednisolone, and prednisolone.

Leutinizing-releasing hormone agents or gonadotropin-releasing hormone antagonists are used primarily in the treatment of prostate cancer. These include leuprolide acetate and goserelin acetate. They prevent the biosynthesis of steroids in the testes.

Anti-hormonal agents include antiestrogenic agents such as tamoxifen, antiandrogen agents such as flutamide, and antiadrenal agents such as mitotane and aminoglutethimide.

ODC inhibitors inhibit cancerous and pre-cancerous cell proliferation by depleting or otherwise interfering with the activity of ODC, the rate limiting enzyme of polyamine biosynthesis important to neoplastic cell growth. In particular, polyamine biosynthesis wherein ornithine is converted to the polyamine, putrescine, with putrescine being subsequently converted to spermidine and spermine appears to be an essential biochemical event in the proliferation of neoplastic growth in a variety of cancers and cancer cell lines and the inhibition of ODC activity or depletion of ODC in such neoplastic cells has been shown to reduce polyamine levels in such cells leading to cell growth arrest; more differentiated cell morphology and even cellular senescence and death. In this regard, ODC or polyamine synthesis inhibitors are considered to be more cytotoxic agents functioning to prevent cancer reoccurrence or the conversion of pre-cancerous cells to cancerous cells than cytotoxic or cell killing agents. A suitable ODC inhibitor is eflornithine or α-difluoromethyl-ornithine, an orally available, irreversible ODC inhibitor, as well as a variety of polyamine analogs which are in various stages of pre-clinical and clinical research.

Other cytotoxics include agents which interfere or block various cellular processes essential for maintenance of cellular functions or cell mitosis as well as agents which promote

apoptosis. In this regard, hydroxyurea appears to act via inhibitors of the enzyme ribonucleotide reductase whereas asparaginase enzymatically converts asparagine into non-functional aspartic acid thereby blocking protein synthesis in a tumor.

Compositions of MUC1-variant specific therapeutic antibodies of the present invention can also be used in combination with antibodies to HER-2, such as Trastuzumab (Herceptin (H), or antibodies to the epidermal growth factor receptor ("EGFR"), such as ERBITUX™ (IMC-C225). In addition, the present invention also encompasses the use of MUC1 domain antagonists in combination with epidermal growth factor receptor-interactive agents such as tyrosine kinase inhibitors. Tyrosine kinase inhibitors suitably include imatinib (Novartis), OSI-774 (OSI Pharmaceuticals), ZD-1839 (AstraZeneca), SU-101 (Sugen) and CP-701 (Cephalon).

When used in the treatment methods of the present invention, it is contemplated that the chemotherapeutic agent of choice can be conveniently used in any formulation that is currently commercially available, and at dosages which fall below or within the approved label usage for single agent use.

VIII. Screening Methods

The present invention also provides for methods of screening for compounds that can inhibit the binding of dermcidin to MUC1. Thus, the method of the present invention provides a MUC1 polypeptide comprising the MUC1 ECD sequence. Such a MUC1 polypeptide includes full-length MUC1 and splice variants such as MUC1Y, MUC1X or MUC1Z. The MUC1 may be provided be means of expression on a cell, which may be a cell transfected with a vector that expresses the MUC1 polypeptide (see *e.g.*, Ren *et al.*, 2002; Li *et al.*, 2003), or it may be a recombinant peptide, with also may be a GST-fusion peptide (see *e.g.*, Ren *et al.*, 2002), or as a FC fusion protein (see Example 1). The method also provides for a dermcidin polypeptide, which may be the precursor polypeptide, the mature polypeptide, or a polypeptide equivalent to the Y-P30 polypeptide.

In some embodiments, either an isolated MUC1 polypeptide or an isolated dermcidin polypeptide may be immobilized. The free polypeptide species may be tagged with a suitable indicator such as a fluorescent label (*e.g.*, FITC), biotin, enzyme indicator, or other suitable indicators generally known by those of skill in the art. Screening of inhibition of binding of the two polypeptide species may be undertaken by introducing candidate compounds.

In some embodiments, an isolated dermcidin is provided to a MUC1 polypeptide expressed in a cell. Candidate compounds can be screened by the observation of an inhibition of a demcidin-induced response, *e.g.*, proliferation, anchorage independent growth, internalization

of MUC1 or translocation of the MUC1 cytoplasmic domain to subcellular organelles such as the nucleus or mitochondria.

EXAMPLES OF THE INVENTION

Example 1: Preparation of MUC1Y-EC-FC Fusion Protein

A chimeric protein containing the human FC region and the extracellular domain of MUC1-Y was prepared for use as an antigen. Full-length cDNA of MUC1-Y (Baruch *et al.*, 1997) was constructed in three steps of PCR. In the first PCR, cDNA coding for MUC1 signal peptide was made with the MUC1 primers:

5'-CTAGCTAGVATGACACCGGGCACCCAGTC-3', and

5'-GGAATTAAAAGCATTCTTCTCAGTAG-3'.

Then the primers:

5'-AATGCTTTTAATTCCTCTCTG-3', and

5'-CTTAAGCTACAAGTTGGCAGAAGT-3',

were used for the second PCR to produce cDNA of MUC1-Y without signal peptide. The mixture of first and second PCR products was taken as a template, and the full-length of MUC1-Y cDNA was amplified in the third PCR with the primers:

5'CTAGCTAGC-ATGACACCGGGCACCCAGTC-3', and

5'-CTTAAGCTACAAGTTGGCAGAAGT-3'.

After digestion of both MUC1-Y cDNA and pIRESpuro2 vector (Clontech Lab., Inc) with *Nhe I* and *Aft II*, DNA fragments were separated on 1.2% agarose gel. MUC1-Y DNA was purified and ligated into pIRESpuro2 vector. The construct was confirmed by both enzymes digestion and DNA sequencing.

The cDNA sequence of a human IgG1 FC fragment (SEQ ID NO: 36) with a KL liner sequence at the amino-terminus was cloned in to the expression vector, pEF6/V5.His (Invitrogen Cat# V96120), resulting in pEF6/V5.His-hFc. The cDNA of the extracellular domain of MUC1-Y (MUC1-Yex) was amplified by PCR using the primers:

MUC1/Yex-N-NheI: 5'-CCC ACC GCT AGC ACC ACC ACC ATG ACA CCG-3', and

MUC1/Yex-C-HindIII: 5'-CCA GCC AAG CTT CCC AGC CCC AGA CTG GGC-3',

and cloned, in frame, upstream of the human FC sequence in pEF6/V5.His-hFc resulting in pEF6/V5.His-MUC1/Yex-hFc. The expression plasmid was confirmed by DNA sequencing.

For stable transfection, the expression plasmid was transfected into CHO K1 cells by lipofectamine. Transfected CHO K1 cells were selected by antibiotics, and single clones were

selected and expanded. Secreted chimeric protein was purified by chromatography using protein A column chromatography, depletion of bovine IgG and buffer exchange and concentration.

The chimeric protein as expressed contained the MUC1-Y extracellular domain plus the N-terminal sequence (SEQ ID NO: 1):
MTPGTQSPFFLLLLLTVLTATTAPKPATVVTGSGHASSTPGGEKETSATQRSSVPSSTE
KNAFNSSLEDPSTDYYQELQRDISEMFLQIYKQGGFLGLSNIKFRPGSVVVQLTLAFREG
TINVHDVETQFNQYKTEAASRYNLTISDVSVSDVPFPFSAQSGAG

Upon secretion from the cell, the N-terminal sequence was cleaved resulting in a human FC chimeric protein containing the 102 amino acid MUC1-Y extracellular sequence (SEQ ID NO: 11): FNSSLEDPSTDYYQELQRDISEMFLQIYKQGGFLGLSNIKFRPGSVVVQL
TLAFREGTINVHDVETQFNQYKTEAASRYNLTISDVSVSDVPFPFSAQSGAG

The polypeptide and polynucleotide sequences of the fusion protein are as shown by SEQ ID NO: 70 and SEQ ID NO: 71 respectively.

PAGE gel analysis under unreduced and reduced conditions indicated that the fusion protein forms a dimmer.

Example 2: Identification of MUC1 Ligands Utilizing MUC1Y-EC-FC Fusion Protein

An affinity column was prepared by immobilizing 1 mg fusion protein on 1 ml of packed Aminolink agarose (Pierce) per manufacturer's instructions. Conditioned medium, from ZR-75-1 cells, neat or diluted with 3 vols of cold 20 mM Tris-HCl, pH 7.4 was salt extract (0.75 M NaCl, 2 mM Na2EDTA, Boehringer protease inhibitors, 10 mM MES, pH 6.2) and passed through the affinity column in a cold room at a rate of 1 ml/min. The column was washed with Dulbecco's phosphate-buffered saline and eluted with 2 M NaCl, 2 mM Na_2EDTA. Eluted fractions were monitored in a spectrophotometer at a wavelength of 280 nm.

Eluate was concentrated and desalted using Biomax-5K filtration unit (Millipore) to 50-100 µl. Samples for electrophoresis were prepared by mixing of concentrated eluate with Tricine sample buffer (Bio-Rad), run in 16.5% Tris-Tricine Ready gel (Bio-Rad), and stained with Coomassie Simply Blue (Invitrogen). Stained gel bands were excised, destained in 50% ethanol, 10 % acetic acid, soaked in water and then - in 50 mM ammonium bicarbonate. Standard procedures utilizing DTT and iodoacetic acid were used for reduction and alkylation of proteins. Following washing in water, excised pieces of gel were cut into smaller pieces, dehydrated in acetonitrile, dried, and rehydrated in 50 mM ammonium bicarbonate containing trypsin (Promega). After incubation for several hours at 30°C, generated peptides were extracted and

run on RP HPLC (C18, Wako) column. Collected peaks were analyzed in ion trap MS instrument.

Dermcidin and PLU-1 were identified as putative ligands.

Example 3: *In Vitro* Treatment Models

Cells that endogenously express MUC-1 such as A549 human non-small cell lung cancer; T-47D and ZR-75-1 human breast cancer cells. Non-MUC1-expressing cells can be transfected, *e.g.*, HCT116 or SW80 human colon cancer cells can be transfected with pIRES-puro2 or pIRESpuro2-MUC1 as described (Li *et al.*, 2001b).

HCT116 and SW80 cells are cultured in Dulbecco's modified Eagle's medium/F12 with 10% heat-inactivated fetal calf serum (FCS), 100 units/ml penicillin, 100 μg/ml streptomycin and 2 mM L-glutamate. A549, T-47D and ZR-75-1 cells are grown in RPMI1640 medium supplemented with 10% fetal bovine serum (FBS), 100 units/ml of penicillin and 100 μg/ml of streptomycin.

Cells are treated with a MUC1-EC fusion protein, e.g., the MUC1Y-EC-FC fusion protein of Example 1, alone or in addition to chemotherapeutic agents such as cis-platin (CDDP) or etopside or agents that induce oxidative stress such as H_2O_2. For example, cells may be treated with 10, 50 or 100 μM CDDP for 8, 24, or 48 hrs in the absence or presence of an effective amount of a MUC1-EC fusion protein.

Cell are evaluated apoptosis by analysis of sub-G1 DNA, TUNEL staining or annex-V staining (Ren *et al.*, 2004).

Example 4: In Vivo Treatment Model

MUC1 transfected mice, *e.g.*, HCT116/vector or HCT116/MUC1 cells ($1x10^6$), or endogenously expressing MUC1 cells, *e.g.*, ZR-75-1 cells ($1x10^7$) are injected subcutaneously in the flanks of 4 to 6-week old female nude (nu/nu) mice. Tumors (*e.g.*, 4 mice/group) are measured twice a week in control and mice treated with suitable amounts of a MUC1-EC fusion protein. Tumor volumes are calculated by the following formula: ½(length x width^2). Experiments are terminated when tumor volume exceeded 2 cm^3.

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The following references, to the extent that they provide exemplary procedural or other details supplementary to those set forth herein, are specifically incorporated herein by reference.

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